

Broadband Communications

The present invention relates to a communications network, in particular to a communications network having a communications station for example a telephone exchange, and at least one interface, for example a cabinet.

In recent years, particularly with increasing use of the internet, there has been an upsurge of interest in providing higher data rates to users. One objective of development in this area, in countries with a heavy historical investment on copper access networks, has been to make use of existing twisted-pair telephone lines. One result of this has been the Asymmetrical Digital Subscriber Line (ADSL) approach in which it was found that an existing copper pair from a telephone exchange to a telephone subscriber's premises could, using suitable modulation techniques, support significant downstream data rates, of the order of 1.5Mbit/s. However the actual rate obtained in practice depends on the quality and length of the path from the exchange and an alternative proposal, providing higher data rates is to make use of the copper pair only from some point rather closer to the user. This is sometimes referred to as very high speed Digital Subscriber Line (VDSL), and these technologies tend to be referred to generically as "xDSL".

Figure 1 illustrates such an "fibre to the cabinet" arrangement. A telephone exchange 1 provides telephony service via cables 2 (perhaps containing 1000 twisted copper pairs) to street cabinets (or cross-connect points) 3, from which rather smaller twisted-pair cables 4 feed distribution points 5. Individual twisted pairs 6 feed from the distribution point to subscriber's premises 7 to feed telephone equipment 8. Broadband service is provided from the exchange 1 by a multiplexer/demultiplexer 9 which multiplexes signals, using ATM or SDH techniques, onto one or more optical fibres 10, feeding the cabinet 3, and similarly demultiplexes signals travelling in the opposite direction. Within the cabinet 3 is (for each fibre) an optical receiver 11 and transmitter 12, demultiplexer 13, multiplexer 14 and xDSL modems 15 which are then connected via filters 16 to the copper pairs of the cable 4 leading to the distribution point 5 and thence via the pairs 6 to the subscriber premises 7 where a filter 17 separates (in the case of downstream signals) and combines (for upstream traffic) conventional telephony signals on the one hand and xDSL signals for data equipment 18 on the other. A power supply 19 is also provided in the cabinet to supply power to the receivers 11, transmitters 12, demultiplexers 13, multiplexers 14 and modems 15.

According to one aspect of the present invention there is provided a telecommunications network comprising:

- a telephone exchange (or a communications station);
- electrical transmission lines connecting the exchange (or the communications station) to user terminations;
- data transmission means;
- optical carriers connecting the data transmission means to at least one interface, located between the exchange (or the communications station) and user terminations, for converting optical signals from an optical carrier into electrical signals for transmission over at least one of the electrical transmission lines;

wherein, for each of a plurality of user terminations requiring data service:

- (a) a dedicated one of said optical carriers is provided;
- (b) the data transmission means comprises modulation means for converting input data signals into output signals suitable for transmission over the electrical transmission lines, followed by means for modulating the output signals onto an optical signal;
- (c) the interface has optoelectrical conversion means arranged to recover said output signals and feed them to the electrical transmission line serving the relevant user termination.

Other aspects of the present invention are provided in the appended claims.

At least some of the user terminations may include respect connection points connecting a user termination to a plurality of further end points, the "user" for example being a network operator. The communication network, in particular the communications station may include a provision for a telephony service, including an exchange.

The optical carriers may be carrier waves, different carrier waves having different frequencies, so as to form respective wavelength channels. In order to carry data, each optical carrier can then be modulated with the data to be carried over that carrier. In this situation, at least some of the carrier waves will preferably be transmitted over a common transmission medium, such as a common optical fibre, in a wavelength division multiplexed manner. Wavelength division multiplexing means such as a wavelength-dependent coupler means will preferably be provided at the

exchange, to allow different wavelength channels to be combined over a common optical medium.

Alternatively, the optical carriers may each be formed by a respective optical transmission line, such as an optical fibre. The optical fibres may be grouped so as to form an optical fibre cable.

Some embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is an example of part of a prior art network;

Figure 2 shows schematically part of a network according to the present invention;

Figure 3 shows a further embodiment of a network according to the present invention;

Figure 4 shows a yet further embodiment of the invention; and,

Figure 5 shows some features of a possible modification to the embodiment of Figure 2.

Figure 2 shows part of a telecommunications system in accordance with a first version of the invention, which is similar to that shown in Figure 1 in that it utilises optical fibre from the exchange to the cabinet, whilst from the cabinet to the subscriber premises it shares the twisted-pair lines with conventional telephony. In this arrangement, however the aim is to reduce the amount of electronics installed in the cabinet. In this particular version, the optical fibre is used only for downstream transmission; upstream data transmission (if required) is provided using the copper pairs from the subscriber premises to the exchange, using the same techniques as in a conventional ADSL system, via modulators 30 in the subscriber's data equipment and demodulators 31 in the exchange 1. No multiplexing is employed on the optical fibres 10, so one fibre 10 is provided for each of the subscriber lines 6 that is to be provided with broadband service. No demultiplexers are employed in the cabinets 4. Moreover, appropriate modulation for converting digital data into a form suitable for downstream transmission on the twisted pairs 4, 6 is provided by xDSL modulators 32 in the exchange 1. These modulators are conventional and operated in the same manner as the modulator parts of the modems 15 of Figure 1, using any technique suited to the purpose, for example, discrete multitone (DMT) modulation, or carrierless

amplitude/phase (CAP) modulation. The modulated output of each modulator then modulates a laser 33.

In the cabinet 4, it is merely necessary to convert the modulated optical signal received over the fibre 10 into electrical form, and apply this signal via a suitable high-pass filter 34 to the appropriate pair within one of the cables 4. In this, the simplest implementation of the invention, this conversion is performed by zero-bias PIN photodiodes 35, and then supplied to the cables 4 via high-pass filters 26. No power supply to the cabinet is required. Since the frequencies would be low (less than 1GHz) a large area diode could be used, allowing simple low cost alignment, and high power operation (typically 0 to +10 dBm).

At the subscriber premises, the downstream signals are received from the splitter/combiner 16 (shown as separate high-pass and low-pass filters 16a, 16b) by an xDSL demodulator 36.

Note that it is not necessary that the interface between the fibres 10 and the copper cabling should occur in the cabinet 4, as it could equally well occur at the distribution point 5 or indeed other intermediate location between the exchange and the subscriber's premises.

If however it is preferred to provide photodiode bias, this could be provided by means of a local power supply, by drawing power from the d.c. applied by the exchange to the line 2 (for example as shown at 39 in Figure 2 for one diode), or by supplying power from the subscriber premises over the pair 6.

If one prefers not to provide an upstream data path using copper all the way back to the exchange as envisaged in Figure 2, then one could use the fibres bidirectionally, as illustrated in Figure 3. Here the downstream arrangements are as described with reference to Figure 2, but the subscriber has an xDSL modem 40 which is entirely conventional. In the cabinet 3, the upstream signals from the line 4 are fed via a high-pass filter 41 to a laser diode 42 to generate an optical signal which is received by a photodiode 43 at the exchange 1 and supplied to an xDSL modem 44. The high-pass filters 36,41 are tuned to the respective parts of the frequency spectrum corresponding to downstream and upstream signals respectively. Note that in fact it is not essential that the equipment 33, 43, 44 be sited at the exchange 1, as they could if desired be at some other exchange, or any other location to which the fibres 10 can conveniently be connected.

In a yet further modification, in order to reduce the amount of fibre required, some of the above features could be combined with a WDM PON as shown in figure 4. The subscriber has an XDSL modem 40 which is connected to an individual twisted copper pair 4. In the cabinet 3, the upstream electrical signals from the line 4 are fed via a high-pass filter 41 to modulate the optical signal produced by a laser diode 42. The laser diode 42 consists of a Fabry-Perot laser diode which in a free running state would generate light at a series of wavelengths whose wavelength spacing is regular and determined by the properties of the laser diode. The laser diode is arranged so as to predominantly generate light at one wavelength determined by the wavelength of an optical seed signal which is fed to it, in this example from the exchange 1 (See Refs 1 and 2). For example, figure 4 shows light over a broad range of wavelengths being generated by a broadband light source (e.g. erbium doped fibre amplifier) 45 in the exchange 1 and fed via an optical circulator 46 to an optical fibre 10. In the cabinet 3 the optical fibre is connected to a wavelength dependant splitter/combiner 47 such as a thin film filter or arrayed waveguide grating which selects a particular wavelength λ_{LN} and passes it to the laser diode 42. The laser diode then generates light at wavelength λ_{LN} modulated with the upstream data and transmits it via the wavelength dependant splitter/combiner and the optical fibre 10 to the exchange. In the exchange the optical signal passes via the optical circulator 46 to a second wavelength dependant splitter/combiner 48. The wavelength dependant splitter/combiner 48 is connected to a plurality of photodiodes 43 which each receive light at a particular wavelength (each wavelength carrying upstream data from a particular customer which is thus supplied to an XDSL modem in the exchange).

In the downstream direction, a second broadband light source 49 generates light at over a different band of wavelengths to the first light source 45. For example, if the first and second broadband light sources 45 and 49 were erbium dopes fibre amplifiers then one could supply wavelengths in the so called "C-band" and the other in the so called "L-band" [of an ITU standard]. The broadband light source 49 is connected via an optical circulator 50 and a further wavelength dependant splitter/combiner 51 to a set of laser diodes 52, which again consist of Fabry Perot laser diodes. In this way each of the laser diodes 52 generates light at a different wavelength depending which port on the wavelength dependant splitter/combiner it is connected to. Each of the laser diodes 52 is modulated with the downstream output from one 321 322 of a set of XDSL modulators in the exchange 32. The modulated downstream optical signals from the laser diodes 52 pass from the exchange along the optical fibre to the cabinet

3. Simple 1x2 WDM optical wavelength band splitter/combiner filters 53 and 54 allow the optical signals produced by each of the two broadband light sources to share the same single optical fibre. The transmission of the wavelength dependant splitter/combiner 47 as a function of wavelength is periodic such that the upstream and downstream data for a particular customer propagate along the same optical fibre. On arriving at the cabinet 3, the modulated downstream optical signals are passed by the wavelength dependant splitter/combiner 47 to a device such as a zero-bias PIN photodiode 35 which converts the signal to an electrical form and applies it via a suitable high pass filter 26 to the appropriate twisted copper pair 4 for the customer. Optionally the laser diodes 42 and photodiodes 35 located in the cabinet could be fed with a low level of dc power from the subscriber premises or exchange over the or a copper pair . It is not necessary for the interface between the fibres 10 and copper cabling to occur in the cabinet 3 as this could equally occur at the distribution point 5 or indeed other intermediate location between the exchange and the subscriber's premises. Furthermore, the broadband light sources (e.g. 49) and laser diodes (e.g. 52) in the exchange could alternatively be replaced by a set of wavelength specified DFB lasers.

In a yet further modification, the photodiode 35 and laser 42 in Figure 3 could be replaced by an electroabsorption modulator serving both to detect the downstream optical signal, and modulate the signal for the upstream path. It employs a two way fibre link from the cabinet to the exchange and utilises an electroabsorption modulator to both detect the optical signal on the down path, and modulate the signal for the return path. xDSL modulation would be applied to the laser within the exchange which would terminate optically on the modulator either in the cabinet or at the DP. The return xDSL signal from the subscriber end would be applied to the modulator which in turn would modulate the optical signal reflected back to the exchange. Given that the upstream and downstream signals are separated in frequency, demodulation becomes a matter of appropriate passive filtering. It is envisaged that the modulator would operate in reflection mode thus requiring only one fibre. Separate contacts could be used to define detector and modulator sections which could be combined with dual wavelength operation.

A modification of part of the system of Figure 2 is shown in Figure 5 (like components are given like numerals). Here, the lasers 33 are configured to transmit at different respective carrier frequencies. A wavelength division multiplexer 33, at the exchange, is arranged to receive the signals from the respective lasers, and to transmit

the signals as a wavelength division multiplexed signal over a common link, for example a common fibre 101. A corresponding wavelength division demultiplexer 332 at the cabinet 3 receives the wavelength division multiplexed signal from the common fibre 101 and demultiplexes the signal. The demultiplexed optical signals are then passed to respective photodiodes 35, which photodiodes provide respective electrical signals to xDSL demodulators 36; in a similar fashion to that shown in Figure 2. In this way, multiplexing the signals between the exchange 1 and the interface 3 reduces the number of optical fibres required between the exchange and the interface.

With embodiments of this invention, the data for each customer or each termination unit can be transmitted in DSL format, from the exchange - over an optical fibre for at least part of the journey and over a copper pair for the remainder of the journey. One advantage of this is that the equipment at the cabinet/kerb could be passive and require no electrical powering or at least much reduced optical powering of a level which could be safely delivered over telecommunications copper pairs..

Electroabsorption modulators are described in our international patent application WO98/04057.

The following references are incorporated herein by reference:

1. A low cost WDM source with an ASE injected Fabry-Perot semiconductor laser", IEEE photonics technology letters, volume 12, number 8, August 2000, pages 1067-1069
2. Hybrid WDM/TDM pon for 128 subscribers using wavelength – selection – free transmitters". OFC 2004 conference, post deadline paper PDP4.